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THE PROFESSIONS OF SCIENCE IN AMERICA: THEIR AMBIVALENT HISTORY

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Prepared for Delivery in the
Notre Dame Lecture Series on
The Professions in American History
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ABSTRACT

Science started to become professionalized in the United States during the Jacksonian period. A principal aim of professionalization was to secure the goals and standards of research from interference by laymen by the institutionalization of scientific autonomy. Then and since, the scientific professions have sought to legitimate themselves by promising various quid pro quos to the society in exchange for the privilege of autonomy. The promises have included the claim that the study of science would foster morally disinterested habits of thinking and that the results of research would lead to practical, material benefit. Since the turn of the century, the claims of legitimation have in many respects been substantially validated, and the scientific professions have grown and prospered. But the very success of science, particularly after it became a favored ward of the federal government, combined with the arrangements of autonomy to provoke popular resentment and, in the era of Vietnam, rebellion. The turmoil revealed that the American scientific professions, at once respected and suspected, esoteric yet indispensable, were destined to live in tension with the larger society indefinitely.

The professionalization of American science is in significant and often overlooked respects a product of the history of democracy in the United States. It is a commonplace of western belief that science is an ally of democracy. And in many respects it has been, from the Englightenment to our own day. We Americans still operate under the Enlightenment propensity, fostered by science, for an empirical adventurousness at once corrosive and constructive. Combined with an appeal to natural law, reasoned empiricism undermined monarchical and ecclesiastical authority and promised, through the understanding and control of nature, broad-based material advancement. Yet for all its alliance with anti-authoritarianism and material wealth, science has always been marked by contrary tendencies. The life of science pivots on the exercise of authority and in a special sense it glows with a spiritual fire akin to religion.

The tendency to authority in science derives from the simple fact that all students of nature are not equal in preparation or ability. At the one extreme is the ignorant layman, at the other the esoterically knowledgeable specialist. Even among specialists there is a spectrum of talent. Some scientists have always been better than others, not only in productivity but in quality and judgment. One Newton, Darwin, or Einstein is worth thousands of lesser natural philosophers. Thus science, democratic in its tolerance of diverse opinions, is usually not democratic in the formation of judgments. The validity of the law of gravity can hardly be determined by majority vote. In science, as Joseph Henry, the physicist and Secretary of the Smithsonian Institution, once said, opinions must be "weighed, not counted."[1]

Through the nineteenth century many scientists were religious men who understood the world to be God's creation. To lay flora and fauna away in specimen cabinets or to record the position of the stars and planets was to accumulate a factual variorum of the Creator's imprint on the universe. To study nature was to know God. Then, too, many scientists insisted as an article of secular faith that the universe was worth knowing for its own sake, apart from the material benefits that might proceed from the enterprise. In the nineteenth century such scientists distinguished between "abstract" and "practical" science just as later generations would distinguish between "basic" and "applied" research or between "science" and "technology." Henry A. Rowland, the Johns Hopkins University physicist, evoked widespread applause among his fellow students of nature when in 1883 he asked in a public address "what must be done to create a science of physics in this country, rather than to call telegraphs, electric lights, and such conveniences by the name of science . . . The cook who invents a new and palatable dish for the table benefits the world to a certain degree," Rowland observed; "yet we do not dignify him by the name of chemist."[2]

If Rowland manifested a certain dissatisfaction with his country, his predecessors of the late eighteenth century felt more at home in their America. Benjamin Franklin happily combined practical invention with philosophizing upon the nature of electricity. Thomas

Jefferson was no less interested in the flora and fauna found by Lewis and Clark for their own sake as for their implications for westward expansion. At the turn of the nineteenth century, American society was comparatively stratified, its churches generally pervaded with the tolerant spirit of the Enlightenment. The higher learning was generally free of untoward pressure from priestly concerns on the one side or from materialist demands on the other. Natural philosophers of the day were able to maintain a happy balance between God and knowledge, between the abstract and the practical.

Yet as the nineteenth century progressed, the balance grew precarious. For as the common man demanded and increasingly won his just rights, he worked a social, religious, and political change in American society that the scientific community perceived to threaten the pursuit of knowledge for its own sake and its accustomed insulation from lay interference. Joseph Henry complained in the 1840s: "Our newspaper are filled with puffs of quackery and every man who can . . . exhibit a few experiments to a class of young ladies is called a man of science."[3] Any dabbler who collected natural specimens or fiddled with an electrical battery might expect to deliver his results before a scientific meeting or publish them in one of the scores of local scientific journals. Even the principal organ of research in the country, the American Journal of Science, depended upon subscriptions from numerous amateurs, its editor aptly observed. To a significant extent for the sake of protecting science against the invasion of a vulgar democracy, natural philosophers in America turned to professionalization. It was no accident that the professionalization of science in the United States began with the Jacksonian period, with its democratic assault upon traditional secular and religious authority, and that it came to flourish in the era of Ulysses S. Grant, with its celebrations of material progress so annoying to Henry Rowland.

According to the model advanced by the historian George Daniels, the professionalization of American science occurred in four overlapping stages: preemption, institutionalization, legitimation, and, finally, professional autonomy. Daniels' is a useful model that helps formalize the anti-democratic tendencies in the professionalization of science. The preemptive stage is provoked by the increasingly esoteric quality of natural knowledge, of the march of learning beyond mere fact-gathering to complex relationships, to systematics, to theory. In botany, for example, preemption followed on the spread of the Linnaean system, with its categories of species, genus, and type. Only specialists could classify new specimens, not the mere Sunday naturalist. The point in time of preemption may have varied with discipline, but in all disciplines it worked a similar effect -- the exclusion of the lay amateur from scientific discourse.

The institutionalization of exclusiveness was no mean task in democratic America. There were numerous local scientific societies in the United States. Most, Rowland ruefully observed, were "dignified by high-sounding names," and each had "its local celebrity, to whom the privilege of describing some crab with an extra claw . . . is inestimable."[4] At the national level in 1844, professionally-minded scientists formed the American Association for the Advancement of

Science. To be sure, membership was open to any interested layman willing to pay the dues, but the constitution of the AAAS virtually guaranteed the election of professional scientists to the governing offices, including a standing committee whose approval was required for the presentation of a paper at the meetings or its publication under AAAS auspices. Narrowing matters still further, in 1874 the constitution was revamped to restrict officeholders to a new, special class of members, or "Fellows," accomplished in research. Still more exclusive was the National Academy of Sciences, founded in 1863, admission to which required distinction in research and election by the existing, limited membership.

Amid the proliferation of specialized knowledge, no single society or association could expect to accommodate the interests of the diverse groups of scientists that steadily sprang up in the United States. If scientists wished to insulate themselves from laymen, so chemists wanted to protect themselves from entomologists, physicists from natural historians, etc. Pursuing professionalization to its logical end, specialists in various fields began after the Civil War to organize special societies. The first in science was the American Chemical Society, founded in 1876. Soon following suit were geologists, astrophysicists, botanists, physicists, and mathematicians. Like the AAAS, most of these professional societies opened their membership rolls to the general, interested public, but they also restricted control of the organization -- of its offices, budget, journal, and meetings -- to an elite accomplished in research.

After the Civil War, the trend to professionalization in science spread to institutions of higher learning. Recent scholarship has made clear that the _antebellum_ colleges by no means ignored science. Physics, mathematics, natural history, and often more were standard parts of the required curriculum. But the courses were taught largely by rote rather than with laboratory experience. Hardly any college taught them beyond the elementary level. And there was no graduate training to speak of in science or any other subject. But in the post-Civil War decades, a new generation of college presidents revolutionized the higher learning in America. They fostered the introduction of laboratory work in scientific courses and created the elective system, which, liberating students from the constraints of a required general education, permitted them to pursue courses in a given specialty to an advanced level even as undergraduates. And, following the lead of Daniel Coit Gilman at The Johns Hopkins University, they established graduate schools devoted to training students in research.

American scientists were gladdened by the creation of the university system. Not only did it advance their self-interest through the institutionalization of their professional aims. It also helped accommodate the exclusiveness of professional culture to democratic aims and assumptions. For if professionalism meant exclusion, the new higher education meant accessibility. Scientific training, both undergraduate and graduate, would make for a continuing supply of new knowledgeable talent, while the process of certification inherent in graduate work would permit the regulation of entrance into science only of people qualified to pursue professional work.

The wiser leaders of American science recognized that in the United States, which, unlike Europe, had no monarchy or formal aristocracy to supply the patronage of learning, it might be dangerous to carry the exclusiveness inherent in professionalization too far. And if they insisted upon independence and autonomy for science, they recognized that the larger society would expect a return for allowing them such privileges. The return they promised, what Daniels has called the legitimation of professional science, took the form, in part and for a while, at least, of calling continued attention to the way that the study of nature would fortify religion by revealing God's handiwork in the universe. But the natural theological content of scientific legitimation fell rapidly away after Darwin unleashed his theory of evolution and society grew more secularized.

The more long-lasting claims of legitimation -- they remain with us today -- centered on three points: First, that the study of science fostered disinterested, even moral, habits of thinking, that science, in the words of Charles William Eliot, the onetime chemist who headed Harvard for forty years, "ennobles and purifies the mind."[5] Second, that scientists, at once expert and morally objective, could be counted upon to supply the nation with indispensable disinterested advice and guidance as it plunged irrevocably into the modern urban, technological age. And third, that the pursuit of abstract, or what by the 1880s was called "pure," science would eventually pay rich dividends, in the technology of material wealth, better health, and, to anticipate a key legitimation of a later day, of national defense.

Yet in the late nineteenth century, American scientists were more successful in pursuing professionalization than in convincing their countrymen to respect such claims of legitimation. The symbolic proprietor of the burgeoning electrical industry was of course not a physicist but Thomas Alva Edison, who once gibed: "Oh these mathematicians make me tired! When you ask them to work out a sum they take a piece of paper, cover it with rows of A's B's and X's Y's . . . scatter a mess of flyspecks over them, and then give you an answer that's all wrong."[6] Geologists from the National Academy of Sciences recommended that the government reform the homestead system, since it was inappropriate to the arid lands west of the hundredth meridian. Theorists had pronounced the homestead system dead before, cried Congressman Martin Maginnis from the Montana Territory. Yet settlers had gone west and, "practical men" all, had "seen the capabilities of this land which had escaped the notice of our scientists and statesmen." In the end, the Congress left the public land system intact. Congressman Dudley C. Haskell of Lawrence, Kansas expressed the pervasive evaluation at the time of scientific advice for public policy. "Now . . . if you want a lot of astronomical figures, if you want a lot of scientific material, then authorize them to get out there and dig and hunt bugs and investigate fossils and discover the rotundity of the earth and take astronomical investigations. But if you please, while you are there acting in the interest of science and in the interest of professional bug-hunting, leave the settlers upon our frontier alone."[7]

Federal policy towards pure research was even less tolerant than Haskell made it sound. In the 1880s the federal government was perhaps the largest single employer of scientists in the United States. Yet Washington was hardly a haven for abstract research. Every federal scientist, beleaguered before the governmental apostles of utility, could understand the defense offered by one of their brethren before a Congressional investigating committee: "We are not fomenting science. We are doing practical work for practical purposes."[8] The principal American arena for pure science was the universities, but there pure science was handicapped, even after the pro-science revolution worked by people such as Charles William Eliot and Daniel Coit Gilman. In the late nineteenth century, the university president exercised virtually autocratic power over his institution, and, with the exception of Gilman at Hopkins, he tended to use that power to foster teaching over research. Eliot and his fellow college presidents had reformed higher education principally for cultural purposes. They respected scholarship more than their old-time predecessors; they believed with the president of MIT that "Our aim should be: the mind of the student, not scientific discovery, not professional accomplishment."[9] In the late nineteenth century, the main object of the university was to develop character by diffusing science and its way of thinking, not by stressing its advancement.

Thus, by the late nineteenth century American scientists may have succeeded in professionalizing themselves, but they had not accomplished the similarly important task of accommodating their particular profession to the values and culture of the American democracy. And the points of tension between themselves and their society centered precisely on their principal claims of legitimation. If they considered pure superior to applied science, most Americans preferred the gadgets and machinery that made for material wealth and comfort. If they thought themselves valuable public counselors, advisors upon technical matters of public interest, the public viewed them as impractically abstract. If they claimed a special virtue, if they insisted that, as scientists, they were suffused with a moral disinterestedness, many Americans could agree with the opinion of the editors of the influential Scientific Monthly, who remarked that, like other men, scientists were "self-seeking, ambitious, and have their personal ends to gain. Can we assume that morally they are any better than their neighbors; or that, if they get possession of place and power, they will not use and pervert them to the promotion of their selfish objects? It is to be hoped that in the future science will become so developed as to react upon character and give us men morally as well as intellectually superior; but we are far from any such happy result as yet."[10]

In the post-Civil War decades, amid the disrespect and lack of opportunities for careers in basic research, there was no general democratization of access to the profession of science. Only a handful of secondary schools provided any scientific preparation whatever, especially in the laboratory sciences of the day. In higher education, the number of scholarships and fellowships was minute; most young people could not afford an undergraduate education, let alone graduate school or study in Europe. Then, too, as a Cornell scientist aptly expressed a widespread belief: "In this country, men devoted to science purely for the sake of science are and must be few in number. Few can devote their lives to work that promises no return except the satisfaction of adding to the sum of human knowledge. Very few have both the means and inclination to do this."[11] As a result, American scientists of the day tended to come from a narrow, upper crust fragment of society. Most were the sons -- or married the daughters -- of well-to-do merchants, gentry, lawyers, ministers, or teachers. Almost all were white Anglo-Saxon Protestants. Almost all were male.

By the late 1880s the American scientific community totaled no more than a few thousand people. Although Edison hired a few physicists, the typical industrial scientist of the day tended to be a consulting or entrepreneurial chemist or geologist, and such people in any case amounted to only a small fraction of the scientific community. By far a more significant scientific employer was the federal government. (In the late nineteenth century, in fact, one budget-cutting Congressman complained that the United States government was spending more for scientific research than all the nations of western Europe combined.) About half the membership of the National Academy of Sciences in the 1880s consisted of federal scientists. But federal science was differentially important with respect to discipline. With the practical purposefulness of government science, Washington was a center of those disciplines understood to be relevant to the government's practical tasks of the day -- exploration and settlement. Thus Washington was a center mainly of the earth rather than of the physical sciences. Geologists, geodesists, or meteorologists were more likely to be found in federal agencies than physicists or chemists. Yet whether involved with the earth or physical disciplines, almost all scientists were employed in the sector of society that only upper crust Americans seemed to consider important, the academic world.

It was with considerable justification that Henry Rowland lamented in 1883 that American science was a thing "of the future, and not of the present or past."[12]

Not long after Rowland's lament, in the 1890s, the scientific community started demonstrating, with growing persuasiveness and at a steadily increasing rate, the validity of at least some of its claims to legitimation. Scientifically trained people, some from American colleges and universities, others from abroad, trickled into industry, often as entrepreneurs. Bringing with them a knowledge of basic science, they gradually introduced a higher degree of technical complexity into chemicals, petroleum, mining, pharmaceuticals, and the like. Typically, they fostered the use of alternating current in the electrical industry, which had hitherto relied on direct current. In DC circuits, simple algebra and an elementary knowledge of electrical phenomena would suffice the engineer. AC circuit analysis required the calculus and training in electromagnetic theory. Symbolically, in the early 1890s Thomas A. Edison sold his firm to a new combine called General Electric and left the light and power business for good. The principal figure in the G.E. technical works was Charles Proteus Steinmetz, a German immigrant with advanced training in physics. As early as the 1890s, Andrew Carnegie, he the apostle of the self-made man, announced that the "trained mechanic of the past . . . is now to meet a rival in the scientifically educated youth, who will push him hard — very hard indeed."[13]

The scientifically trained men entering industry arrived with an important piece of attitudinal luggage, drawn from their teachers′ claims to legitimation -- that the pursuit of basic knowledge would eventually lead to practical and profitable results. Circumstances in the more technologically intensive industries ratified the claim. The chemical industry drew upon basic organic chemistry in such areas as dyestuffs and fertilizers, while the electrical communications industry was compelled, once it began to exploit the vacuum tube, to consider such phenomena as the behavior of electrons in gases. Hungry for the development of basic knowledge in areas of particular interest to their firms, the rising scientifically trained managers adventurously urged their companies in the decade or so before World War I to establish their own research laboratories. Typical of them were Frank B. Jewett, a Ph.D. in physics from the University of Chicago, who inaugurated what became the Bell Telephone Laboratories, and Willis R. Whitney, a product of advanced training in physical chemistry at MIT, who started the research laboratory of General Electric. Many of the scientists hired by Jewett, Whitney, and others were duty-bound to engage in reasonably practical research, but a few were permitted the freedom to roam in areas more remote from the firm′s practical interest.

Among them, at General Electric, was Irving Langmuir, a physical chemist and Ph.D. who had studied in Europe. For some years at G.E., Langmuir explored the behavior of gases in the neighborhood of hot filaments. He contributed tellingly to the fundamental field of surface chemistry, but his research also, virtually by serendipity, pointed to a valuable technological innovation. Electric light bulbs of the day tended to blacken after comparatively short use. The cause tended to be attributed to the air in the bulb, and much effort had gone into attempting to manufacture evacuated bulbs. Langmuir's research revealed that the blackening occurred as a result of interactions between the oxygen in the air and the filament. The key to a more long-lived bulb? Not to evacuate the lamp but to fill it entirely with nitrogen, which did not interact with the filament. With the advent of the nitrogen-filled lamp, General Electric's investment in the ostensibly impractical work of Langmuir was demonstrated to pay enormous dividends, a lesson that was not lost on businessmen in other firms and fields.

Early in the century, professional scientists continued to urge the economic utility of science upon the federal government. Particularly active now were physical scientists, who insisted that, just as Washington had sponsored work in the earth sciences in the era of westward settlement, so in the new century it should facilitate the growing use of the physical sciences, notably physics and chemistry, in the national economy. At the turn of the century, the University of Chicago physicist Samuel Wesley Stratton lobbied for and almost single-handedly persuaded the federal government to create the

National Bureau of Standards, the first scientific agency in Washington devoted entirely to the laboratory disciplines. As its title suggests, the Bureau was created to provide authoritative standards and measures for the diverse materials and physical constants essential to the burgeoning industrial machine. Following in the tradition of his predecessors in federal science, Stratton interpreted his mandate broadly, so that the Bureau became a major center of research in those areas of the physical sciences which underlay the establishment of reliable measures. For many years, in fact, the Bureau employed more physicists than any other institution in the United States.

Yet early twentieth century scientists were alive to more than the economic utility of knowledge. Like their nineteenth century predecessors, many of them advanced the claim to legitimation that professional scientists could provide expert disinterested advice upon the problems of a technological age. Amid the steady growth in the role of government in the nation's increasingly urban and technological life, the claim acquired ever more solidity. In the early twentieth century, geologists, heirs of the great public resources reformer John Wesley Powell, became enmeshed in the formation of federal policy for public lands and conservation; Samuel Wesley Stratton threw the Bureau of Standards into consumer campaigns for honesty in weights and measures. At the Bureau of Chemistry in the Department of Agriculture, the chemist Harvey Wiley helped spark the public debate over questions related to purity in foods and drugs that led in 1906 to the creation of the Food and Drug Administration.

In the early twentieth century, professional scientists came to form an indispensable cadre within the government's expanding regulatory army.

The more the nation's scientific professions seemed to validate their claims to legitimation, the more they grew and flourished. The growth dated from the 1890s, with the appearance of industrial demand for technically trained manpower. American college enrollments started to climb exponentially, and after the turn of the century, despite setbacks in war and depression, they continued to climb in the same fashion. Technical enrollments, particularly in engineering, but also in the sciences, followed a similar pattern. Often students who entered college intent upon careers in industry or medicine discovered that they liked science as such. Their ambitions came to focus on the professoriat, and not unrealistically, for in all fields the increase in undergraduate enrollments stimulated a steady increase in the demand for college and university teachers of science. After the turn of the century, graduate enrollments in science also rose exponentially. In 1920, American universities produced 280 Ph.D.'s in science outside of engineering; in 1939, almost 1,400.

During the period to 1939, the professions of science turned into an avenue of social mobility. While they did not draw from the bottom of American society, they did provide a means by which the children of middle to lower middle class families, often from rural areas, migrated to the urban upper middle class, both in income and in social status. To be sure, the American scientific professions remained overwhelmingly white, Anglo-Saxon, Protestant and male, but between the two world wars they also became an avenue of mobility for one minority group, American Jews.

The Jewish entrance into science turned in part on their group's cultural attachment to learning, in part on their long-standing belief that professional careers, which depended on the unconfiscatable properties of the mind, would better insulate them against the hazards of anti-Semitism, which could lead to the deprivation of property in land or business. (The refugee physicist Abraham Pais once remarked: "The Jew has the tradition of the book first because so it was in the ghetto, but secondly . . . because the contents of the book are inalienable -- even if the book itself is not.")[14] By the end of the 1930s, Jews were represented in American physics at least in proportion to their weight in the overall population. The combined presence of both natives and refugees from Hitler's Europe starred American Jewish physicists with a disproportionately significant role in the leadership of their discipline.

Discrimination did a good deal to keep blacks, Catholics, and women comparatively underrepresented in the scientific professions. But the record of Jewish Americans, who also suffered from discrimination, suggests that discrimination was not the whole story. For obvious reasons, black Americans had no tradition of learning or professional aspiration. National cultural standards discouraged most young women from thinking about careers at all, and careers in science were considered particularly unwomanly. Women who turned to the physical sciences had always to expect the ambivalent salute that

Voltaire rendered his mistress, the brilliant Madame du Chatelet: "A woman who has translated and illuminated Newton . . . [is] in short a very great man."[15] Women with a bent for technical subjects turned to "womanly" pursuits -- schoolteaching, nursing, the practice of medicine, or, perhaps, the study of animate, organic nature. During the interwar years, well over half the women scientists in America were in psychology, botany, and zoology, and more than three times as many women took doctorates in the biological and social as in the physical sciences.

Neither academic discrimination nor Church doctrine played a telling role in producing the low representation of Catholics in the American scientific professions. More important were the pre-World War II poverty of Catholic higher education and of the American Catholic community in general. Still, the Notre Dame biochemist Julian Pleasants once observed: "Ours is not an abject but a discriminating poverty; it lays bare our scale of values by indicating what we feel we can do without." The modern American Catholic, Pleasants noted, placed "a very low value on . . . scientific research."[16] Clannish in the face of the majority's hostility, young Catholics who could afford college preferred to prepare for work among their own group, frequently in the law. Besides, whether they had come from Ireland, or the nations of central and southern Europe, American Catholics generally derived from peasant cultures. In the old country, learning as such had been left to the priests; in the new, as an observer who understood his fellow Irish pointed out, "intellectual curiosity . . . was taboo because it was lazy and nonutilitarian. But," he added, "a `good head for business' -- ah, that was a gift from heaven, indeed!"[17] During the interwar years, more Catholics went to college not only because they could afford it but because it had become an accepted and advantageous way to get into the most admired and financially rewarding of American occupations. But few Catholic students had any taste for careers in pure science, and few actually joined their Protestant and now Jewish peers in the scientific professions.

From the turn of the century through the 1930s, those professions grew at roughly comparable rates in all scientific disciplines, including the physical, the earth, and the biological sciences. All had strong contingents in the academic world. Some, notably chemistry and then physics, carved out solid sectors of employment in industry. For, following the examples of Whitney and Jewett at Bell Telephone and G.E., businessmen and philanthropists increasingly embraced the economic legitimation of science. The circumstances of international trade were enough to convince them that, if the United States were to compete economically in the world, industry had to support research, including pure research. From the 1920s on, industry and industrial philanthropists donated considerable funds to the enterprise of basic science. Part of the money went into the academic world. A great deal of it was invested in industrial research laboratories, some of which devoted at least part of their effort to pure science. A few of these laboratories -- the Bell Telephone Laboratory is an outstanding example -- achieved world rank in their fundamental areas. Indeed, by the 1930s, in most fields, the

United States had taken its place among the leading scientific nations.

The ascendancy occurred without significant federal support of science as we know it. For from the turn of the century through the 1930s, federal science tended overwhelmingly to consist, in the nineteenth-century vein, almost entirely of research related to the practical concerns of the economy or of regulation: The FDA, for example, in order to carry out its statutory responsibilities of assuring the safety of what we eat and drink, had to sponsor an ongoing research program into the hazards of ingestible market products. And most federally supported research was carried out in federal laboratories like the National Bureau of Standards. To be sure, the federal government did begin in 1887 to fund research at agricultural experiment stations located at state or land-grant universities, and that support was enlarged both early in the century and in the 1930s. Still, agriculture was an exception. Before World War II there was no significant federal funding of scientific research, pure or applied, in the academic world.

The reason, in part, was that American scientists were decidedly ambivalent towards the idea of federal patronage. On the one hand, they came increasingly to want the money, particularly in the 1930s, when academic science, like most other areas of American life, was undermined by the depression. On the other hand, they feared federal support because with it might come federal control. The fear was sometimes expressed in terms of Galileo's battle with the church -- that politics would determine what scientists could think and publish. But the more common and profound fear centered on what had helped provoke American scientists to professionalize in the first place: apprehension that, through the instrument of political power, laymen might set the subjects and direction of research.

Whenever the nation's scientific leadership had brushed up against the possibility of federal support for academic science, they had sought to reconcile what they wanted with what they feared. As the means of reconciliation, they usually advanced administrative mechanisms that would permit the flow of federal money into academic research in a way that insulated the flow from direct political control. They justified the demand on grounds of their requirement of professional autonomy, and by insisting that, as moral, disinterested men, they could be expected to spend public funds in the public interest. Again and again, their proposals failed. Politically responsible officials would not go along with such a mixture of public support without public accountability. Unlike other interest groups, which commanded millions of votes or dollars or both, the nation's scientists lacked sufficient political power to force an accommodation with the government on their own terms. Or at least they lacked it until in World War II they validated their most powerful claim to legitimation -- their utility to the national defense.

American scientists, mainly chemists and physicists, had been involved in defense work before, particularly in World War I. They had worked on chemical weapons, aircraft, submarine detection, radio, and the like. For a number of reasons, not least among them the retreat into isolationism, there was no postwar commitment to research for national defense and, during the interwar years, defense research was carried out in military or industrial contract laboratories and, for the most part, did not utilize scientists in the academic world. Yet the experience of World War I had sensitized a number of those scientists involved in it to the necessity and the possibilities of science for military purposes, and as the specter of war rose over Europe in the late 1930s, they decided to act. An exaggerated importance has been attached to the letter that Albert Einstein sent to Franklin D. Roosevelt in 1939, calling his attention to the military potential of the recent discovery of nuclear fission. Einstein's letter was not terribly critical, either for the launching of the ultimate Manhattan Project that produced the atomic bomb or for the wartime mobilization of science in general. Of central significance to both efforts was Vannevar Bush, a veteran of the submarine detection work in World War I, and a small group of similarly experienced men around him, who in 1940 prevailed upon President Roosevelt to establish what soon turned into the spectacularly successful Office of Scientific Research and Development, or OSRD.

Headquartered at Bush's office in the Carnegie Institution of Washington, OSRD established no laboratories of its own. It operated primarily by contract, with industrial and with academic laboratories. Among its largest facilities was the Radiation Laboratory at MIT, which consisted of some 4,000 staff members at its height. Many of the Rad Lab staff were professional physicists, often mere fledglings not yet out of graduate school. The Lab had an academic flavor to it.

OSRD contractors successfully developed not only numerous radars but also solid fuel rockets, proximity fuzes, and myriad other devices that played effective, and often decisive, roles in the war effort. The atomic bomb work was originally conducted under a special section of OSRD, until, when it was sufficiently well along, it was transferred to the Manhattan District of the Army Engineers. After the war ended, Rad Lab workers liked to say, "Radar won the war. The atomic bomb only ended it."[18]

Radar or the atomic bomb, both weapons drew upon advanced physics and required physicists well versed in the intricacies of their discipline. The success of OSRD and the Manhattan Project convinced millions of Americans, ordinary citizens and high policy makers alike, that basic scientists were indispensable to the national defense because they were essential to the advisory system of national security and because they produced the new fundamental knowledge upon which the technology of modern military power rested. The nation's basic scientists thus acquired a degree of political power in America that hitherto they had not possessed. Not based on votes or dollars, their power resided in their command of an esoteric knowledge. They had become a strategic elite in American life, and they exploited their power to construct the postwar system of federal support for science to a considerable extent on their long-standing terms of professional autonomy. They helped create a system of granting agencies that supplied a rich level of funds to academic science with only a loose degree of accountability or control. And they forged an advisory system for federal science, culminating in the establishment of the President's Science Advisory Committee in 1957, that carried them to the center of power while maintaining their independent academic and industrial bases.

In the quarter century after World War II, the professions of science flourished in the United States far beyond the dreams of their pre-World War II, let alone nineteenth century, leadership. The exponential increase in the number of scientists continued. In 1970 American universities produced more than 10,000 doctorates in science outside of engineering, and there were almost a half a million scientists practicing in the United States. The federal budget for research and development burgeoned, reaching some $15 billion per year by 1967. Academic, industrial, and governmental science departments expanded steadily, and American scientists commanded the world, winning the lion's share of Nobel Prizes of the period. Yet despite the apparent ratification of their traditional claims to legitimation, the American scientific professions lived in an uneasy tension with the larger society.

In part, the tension derived from the very success of professional science. Rich, immense, and powerful, it was a salient target for dissatisfaction with wealth, size, and power, particularly on the part of those groups -- women, blacks, and Catholics -- whom it tended not to include. In part, the tension lay in the content of the legitimation, in the strong identification of science with industry and the military. During the depression science had been charged with responsibility for undercutting humanistic values, for making possible a technology that robbed people of their jobs. In the late 1960s these themes were revived, new charges added, and all with the virulence that pervaded the dissent from the war in Vietnam. People, the critic John Leonard observed, tended to blame the perversions of modern technological society on single causes, but the cause most prevalently blamed, and with special animosity among those of a humanist or literary sensibility, was science -- "science," which in Leonard's itemization, "brought you technology . . . ; science, which has steadily reduced the number of things for which God can be held accountable and, thereby, pinned the rap on man . . . that *science*. And those scientists."[19]

Scientists may have proudly claimed legitimation by identifying their works with technological progress. They may have happily accepted the patronage that came with such legitimation from industry and the military. In the era of Vietnam not only exponents of the New Left but many liberals, too, indicted scientists for contributing to the degradation of the environment, the destructiveness of the military, and for advancing a barbarous industrial and military power. Scientists may have taken a certain satisfaction from their involvement in the post-1945 governmental advisory structure. They were considered suspect merely by virtue of association with the military. No matter that some of them had fought to slow the strategic arms race. According to Fred Bramfman, the head of an anti-war research group, such efforts merely meant that the scientists involved in them were "lesser, rather than greater, war criminals. They are dramatic examples of how it is possible to be a moderate, well-meaning, decent war criminal."[20]

Yet in more profound part, the tension between the nation's professional scientists and their society lay in the inevitable conflict between the demands of professional autonomy and the requirements of democratic accountability. Through most of the post-World War II era, the government's scientific advisers had tended to avoid the normal political process of open pressure, advocacy, and debate. "The overwhelming majority had never wanted any part of this," John Fischer, the editor of Harper's, wrote with dismay. "Typically, they regard the political process as something sinister if not dirty; often they treat politicians . . . and sometimes the ordinary voter as well with scarcely veiled contempt."[21] If such attitudes displeased Americans, so increasingly did a salient product of the generally closed-door politics of science -- the penchant of governmental R and D policy for stressing, outside of industrially and militarily relevant work, research in esoteric areas of pure science. How justify enormous expenditures for particle accelerators, critics asked vociferously, when the cities were clogged in traffic, slums, and pollution? By 1970 a growing number of Americans were asking with the respected journalist Meg Greenfield: "As presiders over the national science purse, are the scientists speaking in the interests of science . . . government or . . . their own institutions? Is their policy advice . . . offered in furtherance of national objectives -- or agency objectives -- or their own objectives?"[22]

As a result of the rebellion of the Vietnam era, the scientific professions in America suffered a degree of disestablishment. Among the salient characteristics of the change have been a shaping of federal scientific programs in a way more responsive to social needs, a greater role for laymen in determining research objectives, and a drop in the rate of real growth -- in a number of years it fell to zero or below -- in federal scientific support. But the prestige of the scientific professions, if not the same as in the heady quarter century after Hiroshima, remains at an enviably high level. So does federal funding for R and D. So does the power that the professions of science wield in American life. If Americans are uncomfortable with, and at times rebellious towards, insistently autonomous groups, they also recognize the considerable merits in the claims of legitimation advanced by professional scientists for the last century and a half. Suspected yet respected, esoteric yet indispensable, the nation's professional scientists are bound to operate in tension with their society indefinitely.

NOTES

1. Henry to C. Dewey, Nov. 7, 1859, quoted in Robert V. Bruce, "Democracy and American Scientific Organizations in the Mid-Nineteenth Century," unpublished manuscript, pp. 13-14.

2. Rowland, "A Plea for Pure Science," The Physical Papers of Henry Augustus Rowland (Baltimore, 1901), p. 594.

3. Henry to ______________?, Feb. 27, 1846, quoted in Howard S. Miller, Dollars for Research: Science and Its Patrons in Nineteenth-Century America (Seattle, 1970), p. 7.

4. Rowland, "A Plea for Pure Science," The Physical Papers of Henry Augustus Rowland, p. 610.

5. Quoted in Henry James, Charles W. Eliot: President of Harvard University, 1869-1909 (2 vols.; London, 1930), p. 64.

6. Quoted in Matthew Josephson, Edison (New York, 1959), p. 283.

7. U.S. Congress, House, Congressional Record, 45th Cong., 3d Sess., Feb. 18, 1879, pp. 1202-1211.

8. Julius E. Hilgard, in U.S. Congress, Joint Commission to Consider the Present Organization of the Signal Service, Geological Survey, Coast and Geodetic Survey, and the Hydrographic Office of

the Navy Department, with a View to Secure Greater Efficiency and Economy of Administration of the Public Service . . . , Testimony, March 16, 1884, 49th Cong., 1 Sess., Sen. Misc. Doc. 82, Series 2345, p. 54.

9. Francis A. Walker to Alpheus Hyatt, Aug. 29, 1889, Alfred M. Mayer - Alfred G. Mayer - Alpheus Hyatt Papers, Rare Book Room, Princeton University, Princeton, New Jersey.

10. Popular Science Monthly, 27(Oct. 1885), p. 846.

11. William A. Anthony, in Proceedings of the AAAS, 1887, p. 70.

12. Rowland, "A Plea for Pure Science," The Physical Papers of Henry Augustus Rowland, p. 594.

13. Quoted in Irving G. Wyllie, The Self-Made Man in America (New Brunswick, N.J., 1954), p. 112.

14. Pais to Oswald Veblen, Aug. 19, [195?], Oswald Veblen Papers, Library of Congress, Washington, D.C., Box 10.

15. Voltaire to Francois Thomas Marie de Baculard d'Arnaud, Oct. 14, 1749, in Theodore Besterman et al., eds., The Complete Works of Voltaire (vol. 95; Geneva, 1970), pp. 178-79.

16. Julian Pleasants, "Catholics and Science," Commonweal, 58(Aug. 28, 1953), pp. 511-512.

17. Harry McGuire, Letter to the editor, Commonweal, 9(May 1, 1929), 748.

18. Interview with Lee A. DuBridge.

19. Leonard, "The Last Word: Should Science Be Shot?" New York Times Book Review, July 18, 1971, p. 31.

20. Quoted in "Jason Division . . . ," Science, 179(Feb. 2, 1973), p. 460.

21. John Fischer, "Why Our Scientists Are About to Be Dragged, Moaning, into Politics," Harper's, 234(Sept. 1966), p. 22.

22. Meg Greenfield, "Science Goes to Washington," The Reporter, 29(Sept. 26, 1963), p. 26.